Appendix 8-B. Methyl Bromide Fumigation

This appendix discusses the use of methyl bromide (MB) for the fumigation of buildings, rooms, and sensitive items. Many of the procedures in this document were taken from a Remedial Action Plan (RAP) detailing the tenting and test MB fumigation of a 51,400 cubic feet building (USEPA, 2013). This appendix is organized into the following sections:

- Background Information – Discusses MB properties, contractor qualifications, and site-specific training.
- Site Preparation – Discusses the tasks required prior to actual fumigation including sealing of the site and installation of equipment and monitors.
- Fumigation Process – Discusses the actual fumigation including operational parameters.
- Aeration – Describes the procedures for aeration following fumigation.
- Waste Disposal – Summarizes the disposal of waste generated during fumigation.

Background Information

MB Properties

MB (also known as bromomethane) is a colorless, odorless, and nonflammable gas and is classified as an alkyl bromide. As a liquefied gas, it can be handled as a liquid under moderate pressure (14.4 pounds/gallon). MB is used as a pesticide to control insects, nematodes, weeds, pathogens, and rodents. In the United States, MB is used in agriculture as a soil fumigant, commodity treatment, and quarantine treatment. MB is being phased out under the Montreal Protocol and the Clean Air Act because it has been recognized as a stratospheric ozone-depleting substance.

The chemical properties of MB are summarized in Table 3.

Table 1. Chemical Properties of MB

Odor	Odorless at low concentrations; strong musty or sickly sweet odor at high concentrations
Chemical formula	CH_3Br
Boiling point	3.6°C (38.5°F)
Freezing point	-93°C
Molecular weight	94.95
Specific gravity gas (air=1)	3.27 at 0°C
Liquid (water at 4°C=1)	1.732 at 0°C
Latent heat of vaporization	61.52 cal/g
Flammability limits in air	10-20%
Solubility in water	1.34 g/100 ml at 25°C
Pertinent chemical properties	Powerful solvent of organic materials, especially natural rubber. Liquid MB reacts with aluminum and its alloys to form methylated aluminum compounds that are spontaneously flammable in air (see text below). Reacts with zinc, magnesium, tin, and iron surfaces in the presence of impurities such as water or alcohol. Avoid the presence of acetylenic compounds, ammonia, dimethylsulfoxide, ethylene oxide, oxidizers, and hot metal surfaces. The MSDS in the HASP section provides further details regarding methyl bromide.

MB is odorless at low concentrations but has a musty or fruity odor at high concentrations (greater than 1,000 parts per million (ppm)). Therefore, at normal commodities fumigation concentrations (ranging from 20–400 ppm depending on the pest), MB is odorless. However, for efficacious MB fumigation of *B. anthracis*, the concentrations can approach 60,000 ppm.

Chloropicrin is sometime added to MB gas as an odorant. Chloropicrin itself has been used as a fumigant and acts as an oxidizer. If added as an odorant to MB, chloropicrin may adversely (corrosively) interact with materials, negating the very reason—low corrosive properties—MB may have been chosen as the decontaminant.

MB penetrates quickly and deeply into porous materials at normal atmospheric pressure. Also, at the end of a fumigation treatment, its vapors dissipate rapidly. Further, many living plants have

been shown to be tolerant (at commodities fumigation concentrations) to this gas in insecticidal treatments (MB will harm grass). MB is nonflammable and nonexplosive under ordinary circumstances and may be used without special precautions against fire.

In the absence of oxygen, liquid MB reacts with aluminum to form methyl aluminum bromide. Methyl aluminum bromide ignites spontaneously in the presence of oxygen. **MB should never be stored in cylinders containing any appreciable amount of the metal aluminum and aluminum tubing should not be used for application of the fumigant**.

MB is a toxic chemical. Because MB dissipates so rapidly to the atmosphere, it is most dangerous at the actual fumigation site itself. Human exposure to high concentrations of MB can result in central nervous system and respiratory system failure, as well as specific and severe deleterious actions on the lungs, eyes, and skin. The National Institute for Occupational Safety and Health (NIOSH) lists MB as a potential occupational carcinogen and recommends lowest feasible exposures and an immediately dangerous to life or health (IDLH) value of 250 ppm. Occupational Safety and Health Administration's (OSHA's) permissible exposure level is 20 ppm (80 milligrams per cubic meter (mg/m^3)) with a skin notation, and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) is 1 ppm (3.9 mg/m^3) with a skin notation. See Section VII, Health and Safety Plan (HASP), regarding health and safety issues, personal protective equipment (PPE) selection, public safety information, and MSDS regarding the use of MB.

Contractor Qualifications

Fumigation contractors should meet the following standards before starting work:

- Experience using fumigation chemicals, including MB or similar fumigant such as sulfuryl fluoride. Licensed to use MB or fumigants in the state or city.
- Ability to provide a qualified on-site representative throughout the entire fumigation. The representative should be familiar with the directions for using the fumigant, and warnings, antidotes, etc., shown on the label, on the gas cylinder, and contained in the manufacturer's application manual.
- Personnel adequately trained and experienced in fumigation operations.
- Meet health and safety requirements, including:
    - OSHA Hazardous Waste Operations and Emergency Response (HAZWOPER) training and medical monitoring requirements as specified under OSHA Standard 1910.120 and 1910.134.
    - Medical surveillance program as outlined 20 CFR 1910.120 (b).
    - Respirator protection program as outlined in 20 CFR 1910.134, including self-contained breathing apparatus (SCBA) use.

  - Available first-aid equipment, SCBA, and other safety equipment available before performing fumigation.
  - OSHA requirements for structural fumigation.
- Proof of biological/chemical agent training.
- Familiar with decontamination procedures.
- Have instruments and equipment available for gas detection. All fumigated areas and any adjoining areas that were not fumigated must be tested with a detector prior to worker re-entry.
- The contractor should provide an option of adding chloropicrin as a warning agent during fumigation

Site Specific Training

Site-specific training for all site workers will be conducted before any work activities begin. On-site training will include a comprehensive site orientation, site-specific training on the biological organism and MB, site security, a review of the HASP, and a review of emergency procedures. Also, an on-site job safety briefing will be performed daily prior to workers receiving assignments.

Site Preparation

Prior to beginning the steps outlined in this section, the following is assumed:

- The exclusion zone (hot zone), the contamination reduction zone, and the support zone have been delineated as described in the Health and Safety Chapter XX.
- The fumigation site interior has been prepared as discussed in the Decontamination Chapter XX, Initial Isolation.

Below are the steps, from sealing the structure to placement of biological indicators, required prior to performing the fumigation. Figure 1 shows the layout for a generic MB fumigation. Site-specific conditions may require more or less of each figure element (i.e., humidifiers, heaters, etc.).

Figure X. Generic Methyl Bromide Fumigation Diagram

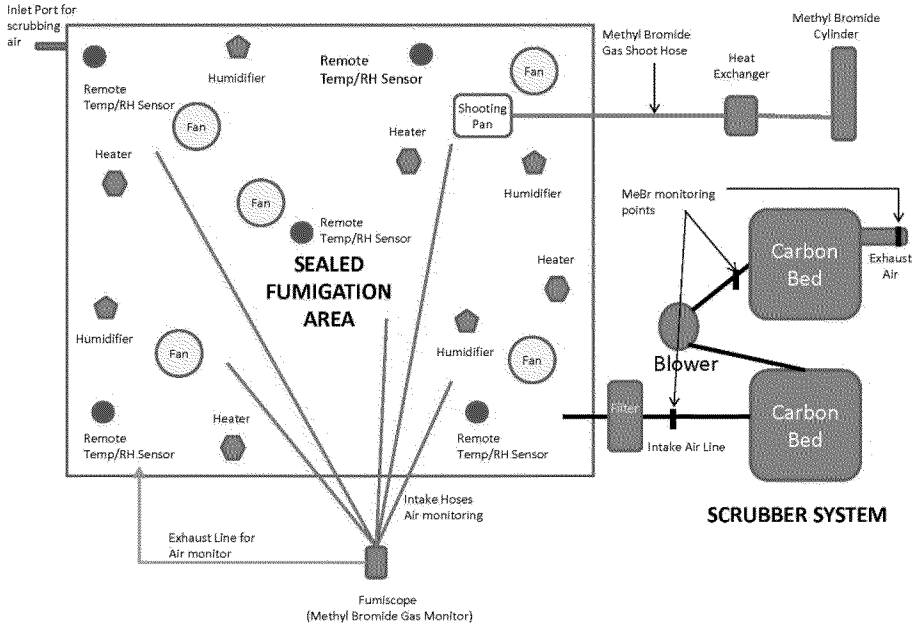

Figure 1. Generic Diagram for Methyl Bromide Fumigation

Sealing, Tenting, and Eliminating Air Leakage

The first step required for fumigation, is to ensure that the entire fumigation area is adequately sealed to reduce leakage of the fumigant. Below is a description of tenting of an entire structures and sealing of rooms and sensitive items.

Tenting

Tenting is the preferred method of isolating an entire building for fumigation. In addition, large-sized or numerous quantities of sensitive items may be tented for fumigation in lieu of surface decontamination of these items. It is recommended that fumigation contractors familiar with tenting of buildings are utilized and that the tenting materials used are compatible with MB. A typical compatible material commonly used is a seven layer ethylene vinyl alcohol (EVOH) tarpaulin. Below are guidelines and procedures that should be followed to ensure proper sealing of the building and flow of the fumigation gas throughout the structure.

- Tarpaulins should be arranged so that ingress and egress openings line up with structural openings which can be used during final aeration.

- Shrubbery and tree branches may be damaged during fumigation. It is best to cut back enough foliage to allow the tent to fall freely to the ground, excluding shrubbery from being inside the tented area. It is recommended to heavily water shrubs, plants and grass adjacent to the structure before fumigation as this will protect the roots.
- Make sure that the surface area outside of the structure is free of debris (gravel, mulch, etc.) by raking or sweeping all debris toward the structure so that the debris is included under the tarp.
- For uneven areas, sand should be distributed around the perimeter of the structure so that there are no gaps between the tarpaulins and the ground. Keep the sand wet during fumigation.
- One-meter-long sand snakes or water snakes, lying end to end around the bottom of the tarpaulins, can be used to secure the tarpaulins to the sand on the ground at the perimeter of the structure.
- A more durable and leak-proof seal can be accomplished by the application of a thick bead of expanding polyurethane foam between the apron of the tarpaulin and the substrate. This will more effectively fill gas penetration paths, even on rough (e.g. asphalt) surfaces, and is easy to remove after the fumigation is completed.
- All penetrations (tears, rips, cuts) of the tarp should be sealed to minimize leakage.
- All building exterior doors, with the exception of those used for building ingress-egress or where air returns to the emitter should be closed. All structure exterior windows will be covered via the tarp material.
- **It is essential that free flow of MB within the structure is allowed during the fumigation process. All measures should be taken to ensure this flow is enhanced including the following:**
    - Open all internal doors and accesses including closet and cabinet doors, desk drawers, refrigerators, and other furniture-like items with closed spaces. Ensure that the opened access points will remain open during the entire fumigation and aeration process.
    - For rooms with drop ceilings, move or remove several drop ceiling tiles in each room so that gas can freely flow between the occupied area and space above the drop ceiling. Use a pole to move/remove tiles to avoid using ladders which introduce fall hazards. Similar for raised floors.
    - For spaces with limited access such as an attic, place a ducted fan at the attic access door with the fan on the ground level and the duct going through the access door and discharging toward the far side of the attic in order to assist the movement of gas through the opening and into the attic space.

Sealing

Sealing is required for fumigation of single rooms within a building and in some instances, may be practical for whole building fumigations in place of tenting. Sealing must be done completely for adequate fumigation and protection of workers and the public from fumigant gas. It is important to understand the layout of the room especially with respect to air flow systems. An initial

walkthrough and talking with a building engineer, if available, is highly recommended. Below is a list of guidelines for sealing a room.

- It is best to use an industrial-strength tape for sealing such as duct tape. Double-sided duct tape (Shuretape) can also be utilized for affixing items (such as plastic sheeting) to surfaces. Also recommended is gas/chemical impermeable tape for sealing (such as Chem Tape). Duct tape can be used as an overlay tape to any other tape used.
- Expanding polyurethane foam can be used as an added measure or for surfaces that tape will not affix to.
- Caulk can be used to assist with sealing any rough surfaces.
- Seal air ducts to prevent cross-contamination of rooms. Air ducts may be sealed by covering with heavy duty plastic sheeting and using tape to seal the edges of the sheeting.
- All windows, door frames, cracks, light fixtures, and floor drains will need to be sealed to prevent the fumigant from escaping the room. Electrical conduit must be sealed.
- Cover and isolate inlet/outlet vents if these lead to other areas.
- For a drop ceiling, it will need to be determined if the space above the panels need fumigation. If required, move or remove several drop ceiling tiles in each room so that gas can freely flow between the occupied area and space above the drop ceiling. Use a pole to move/remove tiles to avoid using ladders which introduce fall hazards. Verify that the perimeter walls are not partial walls that the space above the drop ceiling does not extend beyond the area to be fumigated. Thoroughly assess the area above drop ceilings to check for places that gas can escape. Ensure that external areas outside the room are cordoned off near windows and doors to keep personnel from entering during fumigation.
- If required as part of the final aeration process, ensure that windows can be opened from the outside.
- Following sealing of the room, perform a final check to ensure that all sealing is adequate and there are no gaps or leaks anywhere. Smoke pencils can be used to assist with this task. Guidelines for using a smoke pencil to check for leaks are outlined below.
    - Smoke pencils can consist of smoke-puffer tubes with a manual hand pump or electronic devices which are filled with a non-toxic smoke-generating fluid.
    - When checking for leaks with a smoke pencil, it is recommended to have some air flow entering or exiting the fumigation area so that leaks can be more easily detected (i.e. smoke can be seen being sucked into area or being blown away from area). This can be accomplished by turning on the NAMs, HVAC system, or fans inside the fumigation area.
    - Check for leaks by slowly operating and moving the smoke pencil along seals, cracks, door frames, windows, etc. and look for movement of the smoke either into the sealed area or away from the sealed area depending on airflow. Take into consideration any wind or air flow that may exist outside the sealed area.
    - If any leaks are found, be sure to seal the leak and re-check with the smoke pencil.
- Sensitive items may be fumigated in place (i.e., as part of fumigation of a building or room) or separately in an enclosed structure such as a Conex Box, truck trailer, or tent.

EPA conducted two studies to determine impacts MB might have on sensitive items (EPA, Shannon Serre, August 20, 2014, and EPA, Compatibility of Material and Electronic Equipment with Methyl Bromide and Chlorine Dioxide Fumigation, EPA/600/R-12/664, October 2012). In summary, the studies indicated that MB did not visually impact the materials tested. The edges of computers had some slight corrosion but this was shown to occur because of the chloropicrin added to the MB gas as a warning agent. The materials tested included the following list:

- Historical oil paintings and historical painting surrogates
- Archival documents
- Archival books
- Archival photographs
- Pastel paintings
- Wood/furniture
- Porcelain/bisque
- Fabrics
- Metal objects/metal alloy objects
- Leather
- Aluminum, copper, carbon steel, and stainless steel
- Personal digital assistant
- Cell phone
- Fax machine
- Data dvd
- Desktop computers and monitor

Below are guidelines to be followed for the sealing of sensitive items for fumigation that are not part of a building or room fumigation.

- The size of the enclosure will need to be large enough to accommodate all fumigation equipment and monitoring equipment in addition to the sensitive items.
- Below are specific guidelines for a Conex Box or truck trailer:
  - Follow the same procedures as for sealing a room.
  - Depending on the construction of the enclosure, there may be gaps at corners, drain plugs, or air vents that might need to be sealed.
  - Any duct work, hoses, etc, will need to enter the box or trailer opening. Therefore, it will be necessary to keep the enclosure opened and the openings will need to be sealed using heavy duty plastic sheeting or a tarp. If drain or vent openings can be used for fumigant introduction, then the door opening may be closed and sealed.
  - For MB fumigation, be sure to not use any enclosures that are made from aluminum. Liquid MB is not compatible with aluminum and will react over time. It is possible that liquid MB could be sent through the gas transfer line in the event of a heat-exchanger (volatizer) malfunction.
- For tenting sensitive items, follow the same guidelines as listed under the Tenting section above.

Installation of Scrubber

It is highly recommended that a scrubber system is utilized to absorb the MB prior to its release to the atmosphere for personnel safety and the protection of the stratospheric ozone layer. For MB, the scrubber consists of an activated carbon system (ACS). Approximately 10 kg (22 lb) of activated carbon is required for the adsorption of 1 kg (2.2 lb) of MB, but this adsorption capacity varies greatly depending on carbon type, moisture content, air flow, temperature, humidity, etc. It is recommended that the carbon be distributed in at least 2 vessels, as shown above in Figure 1. At a MB fumigation concentration of 212 milligrams per liter (mg/L) MB, approximately 132 lb of activated carbon would be required for a 1,000 cubic foot fumigation area. It is recommended that approximately 10–20% additional carbon be utilized as a contingency. Note that activated carbon may only be feasible for smaller fumigation volumes as the quantity required for larger volumes may be too large and expensive to be practical.

In addition, a filter should be added prior to the carbon scrubbers. The purpose of this filter is to capture any spores (in the case that the fumigation was not efficacious) prior to the air entering the carbon units.

The scrubber should be placed adjacent to the structure being fumigated and all fittings and piping will pass through into the structure and be tightly sealed. A blower is utilized to pull air from the structure and force air through the activated carbon system. Scrubbing will continue for 24 hours or until the MB has reduced to ≤100 ppm or until the scrubber stack concentration is greater than the structure MB concentration. A monitoring and sampling port for measuring MB concentrations should be included on the exhaust port. Figure 1 shows the setup for a typical air scrubber system. Monitoring of low levels of MB at the stack can be conducted with a calibrated flame ionization detector.

In addition, it is important to ensure that there is a makeup air inlet to the fumigation area for air scrubbing. The air inlet remains closed/sealed off during fumigation but needs to be opened/unsealed for air scrubbing and should be accessible from outside the fumigation area. The makeup air inlet can consist of an air inlet valve, air duct, window, or door and provides fresh air to the structure in proportion to the air that is being removed by the scrubber.

Installation of Gas Monitoring Points

During fumigation it is important to monitor the concentrations of MB gas in the building that is being fumigated. Below are descriptions of a couple of monitors commercially available for measuring MB during fumigation.

- A Fumiscope is a portable instrument that measures the concentration of gases in the air and is designed specifically for fumigation work. In operation, it electrically pumps samples of air from the space being fumigated across a thermal conductivity cell. The concentration of fumigant gas in the air is shown on the digital display in ounces per 1000 cubic feet. Air samples are collected through small tubes placed at critical spots prior to introducing the gas. The tubes can be placed on one or more floors of a multistory structure. Tubes are extended to a convenient spot outside the fumigated structure and readings taken periodically with the Fumiscope. Continuous records are made of gas concentration at each sample tube's location. It can be calibrated for the measurement of MB and the display indicates the concentration in a range from 0–2999 ounces per 1,000 cubic foot (1 ounce is approximately 250 ppm). Make sure that sample tubes, when not being sampled, are closed off so that fumigant does not leak out. Also, the exhaust from the instrument should be connected by tubing to release back into the fumigated structure.
- Spectros Multi-Zone and Single-Zone monitors can be used to measure for MB gases in air during fumigation. Spectros instruments utilize a non-dispersive infrared sensor for the measurement of MB with a working range of 30 to 30,000 ppm. The multi-zone monitor can have up to four gas lines entering it and has a separate readout for each zone on the panel of the instrument. The instrument also has data logging capabilities. Exhaust from the instrument should be connected by tubing to release back into the fumigated structure.

Multiple monitoring locations should be established within a structure to ensure the correct MB concentrations are obtained, maintained, and documented during the fumigation process. The optimal number of monitors and their locations are unique to each structure and should be assessed at each site; however, there should be a minimum of three monitoring locations on each floor of a building and at least one in a room or single enclosure.

Below is a list of guidelines for the MB gas monitoring points:

- The composition of the tubing should be compatible with MB.
- The tubing used should be clean and dry. Do not use the tubing if dirt and/or water are visibly present.
- The exhaust port on the monitor should be connected to the inside of the fumigation site by tubing or through an activated carbon filter to prevent exposure to those operating the instrument.
- Ensure that the appropriate length of tubing for monitoring MB and electrical cables to monitor temperature and relative humidity are positioned during site preparation. The

MB monitor, temperature and humidity readouts should be located outside the structure while the actual measurements are occurring inside the structure.

- A multi-line manifold is useful for keeping tubing lines separate and organized. For the Fumiscope, the tubing line needs to be removed from the control box and attached to the control box for measurement. For the Spectros instrument, simultaneous monitoring of up to 4 lines can be accomplished with the multi-zone monitor. Note that other gas monitors may be available with different configurations.
- Calibrate the chemical detector for MB measurement prior to using per the manufacturer's instructions.
- Check that all gas monitor tubing is labeled and not crimped or crushed. Fumigators should inspect the tubing visually, or use an electric or hand pump to check tubing. A Fumiscope or vacuum pump may also be used to test for unrestricted flow.
- All critical fumigation parameters, including MB concentration, temperature, and relative humidity will be monitored and recorded in a log book at least hourly. The data may also be remotely logged using a datalogger, if the equipment allows for this.

Installation of Temperature and Humidity Monitoring Instruments

It is necessary to remotely monitor the temperature and humidity inside the structure, as these are critical parameters. The sensors for such monitoring should be placed at various locations inside the fumigation site. Monitors are available from several manufacturers, including monitors with wireless sensors that can be monitored from a mobile phone or tablet. Some examples include the following:

- Onset Hobo Data Node - Monitors for temperature and relative humidity and transfers data wirelessly to a computer. Requires software to be loaded onto computer.
- La Crosse Alerts Wireless Remote Temperature and Humidity Monitor – No software or mobile application used. Sensor data is viewed or downloaded anytime by logging into a lacrossealerts.com account with a smartphone, tablet or computer.
- Omega OM-CP-THERMALERT-RH and -P - Monitors for temperature and relative humidity and transfers data wirelessly to a computer. Requires software to be loaded onto computer.
- Oregon Scientific Wireless Temperature and Humidity Sensor with Display – Allows sensors to be placed up to 100 feet from display unit. Does not log data and cannot be used with computer.

Installation of Methyl Bromide Gas Shoot Hoses

Hoses will need to be placed inside the fumigation area for the delivery of the MB gas. A shoot hose is a hose that is connected to a heat exchanger and then placed inside the sealed volume that is to be fumigated. It is a means to transport the hot gas from the heat-exchanger to the volume being fumigated. For multi-story structures, at least one shoot hose location is used on each floor

(approximately one hose for every 50,000 cubic feet). Below is a list of guidelines for installing the gas shoot hoses:

- The hoses will be connected to a heat exchanger (heated, coiled tubing) that is powered by propane or electricity. The MB cylinder is connected by hose directly to the heat exchanger which is connected to the shooting hose (see Figure 1).
- The line that runs from the MB cylinder into the heat exchanger/volatilizer must be a 3,000-psi hydraulic high pressure hose with a 3/8-inch interior diameter (ID) or larger, or in accordance with the manufacturer's MB gas label.
- From the volatilizer/heatexchanger, MB gas is introduced into the structure by means of the gas shoot hoses. These hoses must be a minimum of 200 psi with a ¾-inch ID or larger and the temperature rating of the hose should be 300°F. Do not use polyvinyl tubing; polyethylene tubing or braided chemical resistant tubing is recommended.
- The end of the shoot hose is secured to an evaporating pan or clamped inside a weighted 5-gallon bucket to insure that possible impurities (rust or oil) in the MB cylinder do not splatter on building surfaces.
- Plastic sheeting may be placed under the shoot hose to prevent damage to structural materials.
- A fan will be used to move air past the end of the shoot hose to assist in mixing the MB with the air inside the structure (see below).
- If the structure's HVAC system is operable and assuming that all areas serviced by the ductwork are intended to be treated, the system can be used to circulate air (fan always on) and aid in the decontamination of the structure's duct work. However, it should be noted that if heating is needed, then indirect heating should be used to prevent the formation of hydrogen bromide, hydrobromic acid, and other products through combustion or on a coil.

Installation of Temperature Controls

The ability for MB to inactivate *B. anthracis* spores is dependent on temperature and humidity. It has been shown that at 22°C (71.6°F), 75% relative humidity and a MB concentration of 212 mg/L, *B. anthracis* is inactivated in 36 hours on many types of hard-to-decontaminate materials. To maintain temperatures at or above 22°C (71.6°F), heaters may need to be distributed throughout the fumigation site. Below are guidelines for the placements of heaters:

- Multiple heaters will be distributed as needed throughout the structure. It is recommended that combustion heaters are not used as the fuel used for these can potentially create a flammable atmosphere inside the fumigation area. Examples that may be used include the following:
  - Flameless Therm Dynamics TD500 Portable Heater
  - Pelonis Digital Oil Filled Heater HO-158E, maximum of 1500 watts and delivers 5200 Btu at its top setting
  - Pelonis HO-0221 Electric Radiator Heater, 600/900/1500 watts, 3 heat settings

  - Pelonis HO-0228D Oil Filled Heater.
- Heaters should be controlled from outside the fumigation site to maintain the correct temperature.
- Power lines and lines for controlling the heaters need to be placed inside the fumigation structure prior to the start of fumigation.
- The HVAC system fans may be turned on to decontaminate the HVAC duct work as well as to help circulate air and MB within the structure.

Placement of Fans

Because MB is three times heavier than air, it diffuses outward and downward readily, and requires fans to ensure upward movement and equal gas distribution in a timely manner (MB will equilibrate with air but fans speed up this process). Fans capable of moving 2,500 cubic feet per minute (cfm) or greater should be used during the fumigation, including aeration. Fans must be placed to ensure adequate distribution and is dependent on the specific configuration of the fumigation site (building, room, attic access points).

Placement of Humidifiers

Humidifiers will need to be placed within the fumigation site to achieve and maintain a relative humidity of at least 75%. This level may be difficult to achieve with a standard home-sized humidifier, as the water tank and output capacity are too small for most applications. Industrial-sized humidifiers, whole-house humidifiers, and fogging machines may be necessary to achieve and maintain the desired humidity. The number, placement, and type of the humidifiers will depend on the size of the area being fumigated. Units should be filled with water and allowed to maintain the relative humidity throughout the fumigation. Prior to fumigation, during the setup stage, it is recommended that the humidifiers be used to condition materials in the structure to a higher humidity. The amount of pre-humidification increases with the amount of materials in the structure that will absorb water vapor from the air.

Placement of Biological Test Indicators

Biological indicators (BI) may be deployed as an option to demonstrate adequate dispersion of the fumigant throughout the structure in accordance with an IC/UC-approved SAP. However, it should be noted that unless a good surrogate organism is identified for the BIs, these should not be deployed. Consult the technical advisory team prior to deploying BIs.

Elimination of Flame Sources

Prior to fumigation, extinguish all open flames and turn off all high temperature electrical equipment, including laboratory ovens, pilot lights, gas refrigerators, and oil burners. MB gas in the presence of intense heat from a high energy ignition source may generate some hydrobromic acid which may be injurious to commodities and equipment

Final Check and Placarding

Prior to introducing MB gas into the fumigation site, a final check must be performed to ensure that all equipment is working properly and warmed up. Before beginning fumigation, all external ventilation, bathroom fans (and bathroom lights if connected to fans), HVAC outside air exchange, and negative air machines (air scrubbers), will need to be off. Table **4**. contains a checklist which may be utilized during final check procedures.

Prior to fumigation, placards and signage must be placed on all entrances to the fumigation area. The applicator (or supervisor of the application) must placard all entrances to the fumigated area with signs bearing the following:

1. SKULL and CROSSBONES symbol
2. "DANGER/PELIGRO"
3. "Area and/or commodity under fumigation DO NOT ENTER/NO ENTRE"
4. "Methyl Bromide Fumigant in use"
5. The date and time of fumigation
6. Name, address, and telephone number of the applicator

Table 2 . Methyl Bromide Fumigation Site Preparation Checklist

Y	N	ITEM
		Is sealing and/or tenting adequate (no leaks present)?
		Is air scrubber system in place (including ducts, blower, and monitoring ports)?
		Is there an air inlet to the fumigation area accessible from outside and sealed for fumigation? (required for air scrubbing)
		Are heaters in place and operational from outside the structure?
		Are humidifiers in place, operational from outside the structure and full?
		Are methyl bromide tanks in place and hooked up to the heat exchanger?
		Are fans in place inside the fumigation area and are they on?
		Are methyl bromide monitors set up inside the fumigation site?

		Is exhaust on methyl bromide instrument routed to fumigation site?
		Have flame sources been eliminated?
		Are methyl bromide gas shoot hoses in place in fumigation area?
		If being used, are biological indicators set up inside the fumigation site?
		Has placarding outside the fumigation site been completed?
		Are the remote temperature and humidifier monitors in place and working properly?
		Have gas detection devices been warmed up for at least 30 minutes before zeroing?
		Has fumigation site been evacuated?
		Is the fumigation area locked and sealed?
		Have ambient air monitoring instruments been set up in accordance with the Health and Safety Plan and/or Air Monitoring Plan?
		Are healthy and safety equipment/supplies as specified in the Health and Safety Plan available (PPE, fire extinguishers, etc.)?

Ambient Air Monitoring Planning and Equipment

During fumigation, it is important to monitor for MB vapors in ambient air. An Ambient Air Monitoring Plan (AAMP) to protect workers and the public should be developed along with the Health and Safety Plan. Placement of monitoring instruments will be dependent on the size of the area being fumigated. Below is a list of air monitoring equipment which may be used to monitor for MB. This list is not all-inclusive and other equipment may be utilized.

- Photoionization Detector (PID), a portable instrument that measures for volatile organic compounds and other toxic gases from 1 to 10,000 ppm. PIDs measure the energy required to displace an electron. MB has an ionization potential of 10.54 eV and can therefore be measured by either a 10.6 or 11.7 eV PID lamp. There are several PID instruments on the market which can be utilized.
    - An AreaRAE is an air monitoring instrument containing a PID which can be placed around the perimeter and monitored remotely.
- Draeger makes colorimetric tubes which measure specifically for MB at concentrations ranging from 0.2 to 100 ppm. These tubes cannot be utilized remotely.

The following are guidelines for conducting MB ambient air monitoring outside the fumigation area:

- It is recommended that remote monitoring instruments with data logging capabilities, such as AreaRAE detectors (RAE Systems), are used for ambient air monitoring.

- The number of monitors and locations will depend on the actual fumigation site, surrounding structures, and wind direction.
- The fixed monitors should surround the structure being fumigated at breathing-zone height.
- It is recommended to utilize at least one mobile monitor for leak detection and troubleshooting close in to the structure. Examples that may be utilized include the TIF8800 Leak Detector and the MiniRAE Lite VOC gas detection.
- If additional sampling channels are available on the MB monitor inside the fumigation structure, they may be incorporated into the MB monitoring outside the structure.
- Calibrate monitors prior to use.
- Be sure to record all monitor locations and data collected.
- For instruments that have data logging capabilities, be sure to download the data and appropriately name the file.

If ambient air monitoring indicates a leak of MB during the fumigation process, corrective actions will need to be taken. Corrective actions should include finding the leak location(s) and repairing the leak site. Depending on the levels, it may be necessary to stop the fumigation and evacuate personnel. The HASP will indicate action levels and steps to take should MB exceed the action level outside the fumigated structure.

Fumigation Process

Following the final equipment check, fumigation can take place. It should be noted that certain conditions may require the fumigation process to be postponed or halted (i.e., windy conditions or MB ambient air concentrations).

A volatilizer (heat exchanger) or other appropriate means to heat the liquid MB and speed up its conversion to a gas may be utilized. In addition, chloropicrin can be added as a warning agent. Chloropicrin is a colorless liquid with strong odor that causes eye irritation and tearing when used in small quantities. Cloropicrin is an oxidizer, so material compatibility issues need to be considered.

Table 5 below summarizes the operational parameters for the fumigation process. The time required for fumigation depends on the concentration of MB and the temperature. Based on a laboratory study performed by EPA Office of Research and Development, the following operational parameters have been shown to effectively inactivate *B. anthracis* spores:[1]

Table 3. Operational Parameters for Fumigation

MB Concentration (mg/L)	Relative Humidity (%)	Temperature [°C (°F)]	Duration (hours)
212	75	22 (71.6)	36
212	75	27 (80.6)	36
212	75	32 (89.6)	24
300	75	22 (71.6)	24
300	75	27 (80.6)	18

The quantity of MB required for fumigation is calculated based on the volume of the structure and the desired MB concentration. In addition, there will be sorptive losses due to structural materials and items left in the structure and leakage. Based on hourly monitoring, MB may need to be added during the fumigation to maintain the desired concentration; therefore, an estimated 30–50% more

[1] EPA. *Methyl Bromide Decontamination of Indoor and Outdoor Materials Contaminated with B. anthracis Spores.* August 2014. EPA/ 600/R-14/170.

MB may be needed during the fumigation period based on hourly monitoring results to maintain the desired concentration.

For example, if using a fumigation concentration of 212 mg/L MB, then 6 kg (13.2 pounds) of MB for every 1000 cubic feet of structure volume would be required initially. Therefore, a 10,000 cubic foot area would require approximately 198 pounds of MB [(10 x 13.2)*1.5]. The MB should be stored on site and protected according to state and federal guidelines for cylinder storage.

Below are the steps to follow for fumigation:

- Turn on heaters and humidifiers as needed to ensure that temperature and relative humidity target levels are reached prior to the introduction of MB. This should be done several days ahead of time to allow the materials in the building to reach equilibrium.
- Place fumigant cylinder on a scale and take initial weight reading. After obtaining the weight, subtract the dosage to be introduced into the enclosure.
- Start the volatilizer (heat exchanger) and raise the temperature to 200°F or above. A minimum temperature of 150°F is required at all times during the MB gas introduction process.
- Make sure the gas introduction line is attached to the cylinder.
- Open the valve on the MB gas cylinder and introduce the initial weight of MB required to achieve desired concentration. Check for leaks during introduction of gas. Note that several cylinders of MB may be required to meet the concentration required in the fumigation area. Make sure to follow any instructions on the label. The maximum liquid MB feed rate will depend on the heat-exchanger design.
- Close the valve on gas cylinder.
- Allow gas to equilibrate and check the gas concentrations on gas monitor readouts at each location within the structure.
- Start the fumigation time clock when temperature, humidity, and MB concentrations are all at their desired levels.
- Introduce additional MB gas as required throughout the fumigation process. Check the gas concentrations hourly.
- Respiratory equipment (SCBA) must be available in the event of a major leak or equipment failure.
- Pause the fumigation time clock any time the temperature, relative humidity, or MB concentration goes below the operational limits and restart it once limits are again obtained.
- If MB outside the structure (AAMP monitors) rises above the warning level, then checks will be made for leaks and corrective actions taken to mitigate them.
- If MB outside the structure rises above the Action Level (as stated in HASP), then the fumigation process will shut down until the process can be fixed and outside MB concentrations fall below the Action Level.

- When the operational time limit is achieved, follow the aeration process outlined in the section below.

When determining a decontamination approach, consideration must be given to the contents (e.g., paper, foam, water, fabrics, concrete, galvanized metal, etc.) as they may adversely impact the efficacy of the fumigation. Specific contents, when found in significant quantity, may act as sinks for fumigants, water vapor (humidity), and/or heat. Fumigant adsorption may be followed by latent desorption (off-gassing) for extended periods of time following the initial fumigation. Large amounts of paper, for example, may need to be removed or may need to be pre-humidified before fumigation; and large amounts of foam, may act as a sink for fumigant, requiring the foam to be removed or additional fumigant used to overcome the loss of fumigant to the foam. The interaction of the contents with the fumigant and fumigation parameters will dictate what actions may be needed. However, because interactions are not always known in advance, fumigation parameters must be monitored during the fumigation to assure the parameters necessary for an efficacious decontamination are met.

Aeration

Aeration consists of scrubbing and natural aeration. It should be accompanied by continuous monitoring of MB inside and outside the structure. Fans should continue to operate to help the aeration process. If used, heating and humidity equipment may be terminated; however, heat may also aid the aeration and desorption process.

Aeration should be conducted in the following manner:

- Open the valve at the structure leading to the scrubber, open the make-up air inlet to the structure, and turn the blower on for the air scrubbing system.
- Reduce the MB concentrations within the building to ≤100 ppm or when the MB concentrations at the stack level is equal to or greater than the MB levels at the inlet of the activated carbon scrubber (or whatever level the technical advisory team decides) which will depend on the volumetric flow rate and desorption from materials in the building.
- After MB levels reach the desired concentration, scrubbing ceases.
- Initiate passive (or fan assisted) aeration by opening up the fumigated area. Follow all health and safety procedures prior to doing this. If appropriate, evacuate personnel and the public downwind before opening the area. Ensure that the air monitors are operating and the AAMP is followed.
    - For passive aeration, the fumigation area is opened by personnel in appropriate PPE including air supplied respirators or SCBAs.

- Be sure to aerate anywhere where MB may have become trapped including inside folds of the trap materials.
- Conduct air monitoring both outside and inside the fumigation area until MB concentrations are below 1 ppm.

Clearance sampling and analysis needs to be conducted following the fumigation process in accordance with Section VI, Clearance Sampling and Criteria for Re-Occupancy.

There should be a General Hygiene Plan in place so that the just-fumigated structure is not re-contaminated during the aeration, clean up, and sampling that will happen after the fumigation.

Note Regarding Aeration

After decontamination, a structure is typically aerated to remove airborne concentrations of the decontaminant, returning the structure to a habitable condition. This aeration process can be done naturally by removing any tenting and opening doors and windows. Fans can also be used to assist natural aeration. Aeration can also be done in a more controlled manner using control points for air entry and egress.

Air removed from the structure will include the decontaminant and may include the contaminant if the decontamination process was not successful. Air moving into the structure may carry contaminants back into the structure if the surrounding area is not clean. Thus, depending on site-specific information, controlled aeration may be needed for both the air moving in and out of the structure.

For this controlled aeration process, for health or environmental reasons, there may be a decontaminant scrubber that will remove the decontaminant from the air being removed from the structure. With or without the scrubber, it is recommended that the exiting air be HEPA-filtered to remove any contaminants that may potentially be in the air stream (in the case where decontamination was not effective). If the decontamination process has been effectively deployed and process variables (i.e. concentration of decontaminant, temperature, relative humidity, and time) during subsequent decontaminations, using the same process, are such that there is a high confidence level in the efficacy, then the HEPA-filtration of the air being removed from a structure may be relaxed.

As air is removed from the structure, air will move into the structure to fill the vacuum left by the exiting air. This air is typically called make-up air. If make-up air is not controlled, it will enter the structure through cracks and crevices, taking the path of least resistance. The make-up air may

bring any contaminants that are around the exterior of the structure. Depending on the confidence in the cleanliness of the air adjacent to the structure, HEPA filtration of the make-up air may be recommended.

Formal clearance of the decontaminated area is always required prior to allowing uncontrolled access to the area.

Waste Disposal

Waste generated during the fumigation process will be disposed according all applicable state and federal regulations and in accordance with Section VIII, Waste Management Plan. Wastes anticipated include PPE and activated carbon inside the scrubber tanks.

References

USEPA, Remedial Action Plan for the Field Study of Methyl Bromide Structural Fumigation of a Biological Agent Surrogate on Material Coupons. 2013.